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Groundwater and society: fresh submarine groundwater discharge and its management improvement

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Abstract

Submarine Groundwater Discharge (SGD) becomes a important component in hydrological process that related to biogeochemical and social ecological system. However, no literature has been reviewed about SGD management improvement. This paper explored complex adaptive system to characterize SGD from a social and ecological point of view. Several social and ecological SGD in different countries and continents have been presented to understand SGD phenomenon globally, for instance America, Asia, Africa, Europe, and Pacific Islands. Strategic adaptive managements and Sustainability and Resilience thinking are interpreted to improve the management of SGD phenomenon. Overall, this study identifies SGD related to social ecological and the strategy to improve SGD managements.

Keywords :
submarine groundwater, social ecological, strategic adaptive managements, complex adaptive system

1 Introduction

Having a sustainable, dependable and maintainable control of water sources is a important challenge for maximum international locations across the world (Kalhor et al., 2019). It is determined that simplest three percentage of the whole quantity of water on Earth is regard as freshwater sources. The three percents of Earth's sparkling water is split primarily based totally on continents type as consistent with following (Vallee et al., 2003). Total world's freshwater sources with biggest proportion is America which holds forty five percentage, observed with the aid of using Asia which has 28 percentage, Europe 15.five percentage and finally Africa which has nine percentage of proportion from general of freshwater sources. Freshwater is crucial as humans use it for numerous utility inclusive of drinking, home use, agriculture, business and plenty of more. These freshwaters is coming from 3 most important reassets that is rainwater, groundwater and floor water. Groundwater is water that become located beneathneath the floor land floor in saturated zones (Rihani et al., 2010). Most of the arid international locations, inclusive of Saudi Arabia, Pakistan and Syria use groundwater for irrigation and water supply. It additionally ensu in numerous international locations which has ample rainfall, inclusive of Thailand and Indonesia (Ajaz et al., 2019). Groundwater is carefully associated with the humans's livelihood consequently it's far vital to guard and preserve the groundwater from any pollution and negative control of groundwater sources.

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2 Fresh submarine groundwater discharge (SGD)

Submarine groundwater discharge (SGD) is the flow of groundwater through the sediment water interface and it discharge directly to the ocean, bays, estuaries and any coastal areas (Santos et al., 2021; Zhou et al., 2019). This phenomenon occurs ubiquitously across the globe (Moosdorf and Oehler, 2017). In addition, it is a process composed from oceanographic process, climatologic process and hydro geologic process (Hernández-Molina et al., 2014). The redistributed seawater is estimated to be 90 percent from the total submarine groundwater discharge (SGD) and the remaining 10 percent of discharge volume is attributed from fresh submarine groundwater discharge (SGD) (Moosdorf and Oehler, 2017). Fresh submarine groundwater discharge is controlled by the attribution of aquifer and hydraulic gradient. Several studies have done some analyzation of theoretical model on how both of the factor control the flow of fresh submarine groundwater discharge (SGD) (Liang et al., 2020; Paldor et al., 2020; Wang et al., 2021). However, it is difficult to determine the quantitative data of fresh submarine groundwater discharge (SGD) (Moosdorf and Oehler, 2017). With the permeability of aquifer and the hydraulic gradient controlling together, the amount of water travelling through the aquifer can be detected thus quantitative data can be obtained. Another main factor that control the discharge of fresh submarine groundwater discharge (SGD) is groundwater recharge especially for particular areas with high permeability (Moosdorf and Oehler, 2017). A few studies have discovered that submarine groundwater discharge (SGD) transports a major and notable amount of solutes substances into the coastal water including metal particles and nutrients (Adyasari et al., 2019).

Since it's discovery from about 20 years ago, fresh submarine groundwater discharge (SGD) is considered important especially

as water resources (Moosdorf and Oehler, 2017). Local population at coastal area around the world mainly used it for drinking water supply and other purposes. In Yadua, Fiji, the local villagers were completely relying on water supply from fresh submarine groundwater discharge (SGD) but currently they only use it public water supply is damage (Moosdorf and Oehler, 2017). Meanwhile in Koro Island of Fiji, the locals used fresh submarine groundwater discharge (SGD) for bathing and drinking. Furthermore, in Central Java of Indonesia, the community inhabiting in Gunung Kidul has used fresh submarine groundwater discharge (SGD) for drinking, feeding livestock and also for spiritual event such as praying (Adyasari et al., 2019; Alorda-Kleinglass et al., 2021). The other part of Indonesia, which is Labuhan Lombok, the community there also used fresh submarine groundwater discharge (SGD) as supply for drinking water. The community in Labuhan Lombok, Indonesia collect the fresh submarine groundwater discharge (SGD) from offshore wells as the water supply there has greater purity than the surficial onshore groundwater (Moosdorf and Oehler, 2017). Moreover, in Kiveri, Greece, fresh submarine groundwater discharge (SGD) is formed by damming in the ocean and the local people used it for agriculture (Weinstein, 2021; Santoni et al., 2020). While in Andra Island of Papua New Guinea, the local people wash their clothes and garments at some area on beach after the villagers dug holes on the surface (Correa et al., 2021; Mohamed et al., 2018). Next in Surquillo, Peru, the fresh submarine groundwater discharge (SGD) is pumped out of the wells at the coastal area and the water is distributed to the people by truck (Kim et al., 2017). Based on a few studies, fresh submarine groundwater discharge (SGD) has enhanced the fisheries production in Japan. It improves oyster production in Kamaiso Bay, Japan and in Obama Bay, Japan, the catchment of fishes is greater in water area nearer to fresh submarine groundwater discharge (SGD) than the water area without fresh submarine groundwater discharge (SGD) (Moosdorf and Oehler, 2017).

3 Study of social ecological systems to improve groundwater management

Groundwater has been the only reliable source of freshwater for local people in small islands in Pacific region (Bouchet et al., 2019). It also serves as indicator to social-ecological systems whereby the ecosystems, aquifers and people are all linked together. However, various anthropogenic activities have caused pollutions towards the groundwater resources located at the small islands in Pacific region and thus results in poor quality of groundwater resources (Bouchet et al., 2019). First, agricultural activities such as fertilizing the crops with fertilizers and spraying pesticides to avoid pests from appear on crops have been spreading toxic chemical substances into the ground that eventually reach to groundwater. Same goes to industrial activities that discharge chemical pollutants and solid waste disposal discharge biological pollution to the ground. Some of the Pacific islands such as Funafuti, Tarawa, Nauru, Majuro and Kiritimati are not safe to drink their groundwater resources without advance treatment (Bouchet et al., 2019). This phenomenon has been observed for a long period and this is occurred likely due to the poor sustainable management of resources. Pacific Small Island Developing States (PSIDS) have limited authority towards the management of groundwater and limited authority to monitor the management activities that secure the groundwater (Bouchet et al., 2019). The reasons behind this concern are due to lack of manpower, technical expertise and financial constraints. Other reason that might effect the groundwater management is approaches of control and command that are not properly standardized to the local context (Bouchet et al., 2019). There is no general agreement towards the establishment of national water policies to protect the groundwater resources and to operate the water sectors regularly hence hindered the Pacific Small Island Developing States (PSIDS) to carry out any relevant actions. Moreover, separation of understanding and research to both ecological and social components in groundwater systems has led to the downfall of groundwater resources management (Bouchet et al., 2019).

To restore and mending the groundwater resources management, social-hydrology must be developed and resilience thinking which means how social-ecological-systems assimilates shocks and endure to support both ecosystem and human well-being (Bouchet et al., 2019). Hence, based on a study, a framework has been developed and it consist of three components with detailed working steps which are Strategic Adaptive Managements (SAM), Complex Adaptive Systems (CAS), and Sustainability and Resilience thinking (Bouchet et al., 2019).

Complex Adaptive Systems (CAS) outlines the the groundwater systems characteristics from a social and ecological point of view (Bouchet et al., 2019). This component is served as "what" that represents properties in terms of social and ecological groundwater systems. The study of Complex Adaptive System (CAS) emphasis on how the systems function towards the interactions between the systems (Bouchet et al., 2019). The execution of Complex Adaptive System (CAS) is influenced by these three fundamental properties which are system openness, self-organizations, and nonlinear dynamics and feedbacks (Bouchet et al., 2019). Self-organization is related to the complex systems capability to generate an order whereby the components dealing based on tacit rules without the existence neither central nor external control (Bouchet et al., 2019). Complex Adaptive System (CAS) is adaptive as they have the ability to organize themselves during instability circumstances, absorb the disturbances and return back to a stable condition (Bouchet, Thoms Parsons, 2019). This stable condition can be obtained from Complex Adaptive System (CAS) through the self-organization mentioned above (Bouchet et al., 2019). In terms of groundwater systems, self-organization is able to take place within the three subsystems which is the natural environment like Groundwater Dependent Ecosystem (GDE), the aquifer and local people that lives above the aquifers, and it is able to deliver impact as a whole. Next, this self-organization is taking place through the non-linear dynamics and feedbacks method. Due to the nonlinear dynamics, a change of variable in a system does not always resulting of outcome that is proportional to the change that has been made (Bouchet et al., 2019). While feedback method describes the nonlinear dynamics though the self-organization of Complex Adaptive System (CAS) (Bouchet et al., 2019). The existence of feedbacks exhibit importance of both feedbacks and nonlinear dynamics between the Groundwater Dependent Ecosystem (GDE), groundwater itself and anthropogenic activities (Bouchet et al., 2019). Generally, there are two primary types of feedback which are balancing and reinforcing (Bouchet et al., 2019). Lastly is system openness which is related to the amount of connectivity between the groundwater resources and local communities at greater scales (Bouchet et al., 2019).

Move on to the next component of framework which is Sustainability and Resilience thinking. From the resilience thinking, the study of dynamics of complex systems is possible to include into the framework (Bouchet et al., 2019). This includes the Ecological resilience which means the level of disturbance that an ecosystem is able to withstand without changing any self-organized structures and processes (Bouchet et al., 2019). Resilience thinking has four components that are relevant to Pacific Small Island Developing States (PSIDS) groundwater systems which are the basins of attraction and tipping points, the pre-requisite of resilience for sustainability, the ecosystem services and possible loss that might happen between two stable states, and transformability and adaptability of the system (Bouchet et al., 2019). From all the four components that previously mentioned, they form some sort of understanding that the disturbance which a groundwater system is able to absorb before the tipping point is crossed can lead to the loss of ecosystem service but essentially it is important for the sus-

tainability of groundwater systems (Bouchet et al., 2019).

Last component to be included in the framework is Strategic Adaptive Managements (SAM). Strategic Adaptive Managements (SAM) is a layout of adaptive management and it assists to promote actions and arrange management activities (Stephenson et al., 2019). This Strategic Adaptive Managements (SAM) also permits the establishment of flexible structures to amalgamate a range of knowledge including institutional, cultural, technical and social. Thus, Strategic Adaptive Managements (SAM) produced a strategic, adaptive and participatory process designed by conducting experimental management practices, studying the desirability of the system and review the management practices systematically (Roux et al., 2021). A Strategic Adaptive Managements (SAM) method is able to outline two major issues for groundwater management of the region which are influenced by the characteristics of command and control management (Bouchet et al., 2019). First the dominance of foreign expertise in technical field to design, produce and control the execution of management activities. Second is the mechanical approach towards the groundwater management. Besides that, there are three components associated with Strategic Adaptive Managements (SAM) which are the objectives of hierarchy, learning by doing and Thresholds of Potential Concern (TPC) (Bouchet et al., 2019). The implementation of the framework based on the three components: Strategic Adaptive Managements (SAM), Complex Adaptive Systems (CAS) and Sustainability and Resilience thinking can improve the Pacific Small Island Developing States (PSIDS) groundwater management (Bouchet et al., 2019).

4 Conclusion

Groundwater plays vital roles towards the needs of people as their water resources. Ground water becomes one of the assets of freshwater. Most of the arid international locations, inclusive of Saudi Arabia, Pakistan and Syria use groundwater for irrigation and water supply. Meanwhile in Koro Island of Fiji, the locals used clean submarine groundwater discharge (SGD) for bathing and ingesting. Restoring and modifying groundwater resource management requires developing a social hydrology and resilience mindset, which refers to how social ecosystems absorb and withstand shocks that support both ecosystems and human well-being. Therefore, based on the study, a three-component framework was developed with detailed work steps including strategic adaptive management (SAM), complex adaptive systems (CAS), resilience and resilience thinking. Overall, this study have a look at identifies SGD associated with social ecological and the method to enhance SGD managements concerning those 3 running step control frameworkOverall, this take a look at identifies SGD associated with social ecological and the approach to enhance SGD managements concerning those 3 running step control framework.

Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

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